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Development of Horizontally Adjustable Beam Profile Monitor for the NSLS-II Storage Ring

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Abstract

The NSLS-II Synchrotron Light Source is a 3GeV electron storage ring currently under construction at Brookhaven National Laboratory. During the commissioning phase, there will be a need to profile the beam shape after injection and it will be desirable to have the ability to measure the profile the injected beam as well as the single turn beam in either the stored or bumped positions. Traditional beam profile monitors are typically installed at discreet locations allowing the beam to be viewed in only one position. To view the beam in the injected, bumped and stored beam positions, three profile monitors would be need to be installed at specific locations across the chamber aperture. Here we present a novel design that will have the ability to position the beam imaging screen infinitely between the parked position and the extreme horizontal limit of the chamber allowing the injected, single turn bumped and stored beam profiles to be measured.

NSLS-II construction site taken on 10/9/12 nearing completion.

The unique design of the NSLS-II flag allows for infinite horizontal positioning of the imaging screen by via a movable in-vacuum screen carrier riding on a pair of linear bearings mounted to a specialized chamber. The position of the entire movable assembly is controlled by a high resolution stepper motor actuator.

The physical requirements for this flag were specified by the location where it will be installed. The overall length, entry and exit apertures and flange size are clearly defined. The basic performance requirements of the flag such as image resolution, field of view and horizontal stroke have been specified by accelerator physics.

The flag chamber will also accommodate two sets of RF beam position monitors for measuring positions of bumped and stored beams.

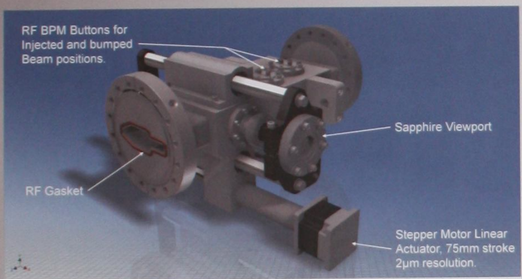

Figure 1: Overall design of the NSLS-II Beam Profile Monitor

Figure 1 shows the overall design of the NSLS-II horizontally adjustable beam profile monitor or flag. This novel design relies on a Cerium doped YAG scintillator screen mounted at 45° in a cylindrical carrier to create a visible image of the electron beam cross section. The visible image is transported down the carrier tube (see Figure 2) and exits through a sapphire viewport. The image is captured on a CCD camera.

Due to the mounting angle, the YAG screen requires an elliptical shape in order to maximize the horizontal viewing area. Since it is difficult to incorporate external calibration optics, a 10mm x 10mm calibration pattern will be etched into the screen.

The screen carrier requires a rectangular aperture adjacent to the screen aperture to allow the injected beam to pass when the screen is in the bumped or stored positions.

Figure 2: Scintillator Screen Carrier Assembly

Figure 3: 3D printing of flag chamber showing upstream beam aperture at injection.

One of the more challenging aspects of the NSLS-II flag was the design of the vacuum chamber. One of the primary requirements was to transition from the exit aperture of the upstream septum chamber to the standard hexagonal aperture of the NSLS-II beam pipe. Our solution utilizes three individual stainless steel sub-components that can be easily fabricated with conventional machining techniques and wire EDM. The three finished components will then be brazed to form a finished chamber. Figure 3 shows a 3D full scale printing of the brazed chamber assembly.

In addition to the flag, this chamber also has provisions for two pairs of RF BPM button assemblies that will allow for positional measurement of the electron beam in the injected and bumped positions.

A unique feature that was incorporated into the flag design is an RF spring installed in the flag penetration. The flag will be parked when beam is circulating but high order modes would be excited within the cavity of the flag bellows. The RF spring is located such that when the flag is in the parked position, the carrier is shorted to the chamber wall, effectively suppressing high order modes.

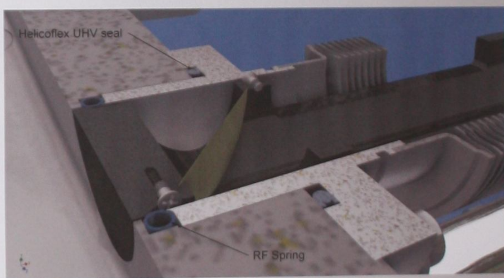

Figure 4: Screen carrier in the parked position. A special slant coil spring is used to short the carrier to the chamber to suppress beam excited high order modes that would form in the bellows cavity.

Figure 5a: Flag adjusted to view injected beam (orange).

Figure 5b: Flag adjusted to view single turn bumped beam (magenta). Injected beam passes through rectangular aperture in screen carrier.

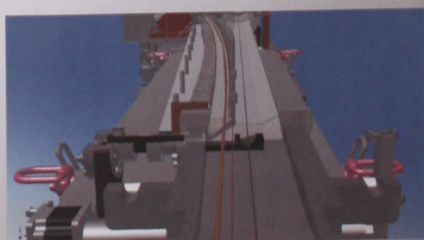

Figure 5c: Flag adjusted to view single turn stored beam (violet). Injected beam passes through rectangular aperture in screen carrier.

The requirements for the flag optics are driven by the necessity to resolve the beam image in the full range of flag motion. From the start we abandoned the idea of moving the camera in synchrony with the flag screen, since this option significantly complicates the overall mechanical design of the flag. Therefore we were left with two possibilities. One can either have the fixed optics, which results in the 75 mm depth of field (DOF), or alternatively one can use remotely adjustable lens, which gives 14 mm DOF (determined by the size of the flag screen). To choose between these two options we performed a set of dedicated tests. Our studies show that the fixed optics provides 100 um resolution. On the other hand, the camera with remotely adjustable optics can provide 50 um resolution. To finalize the optical design for either case, we suggest choosing the lens and camera-to-flag distance that provides several (2-3) pixels per image of the object of 50 um size. The circle of confusion for the given DOF shall be as small as possible and the lens aperture shall be open to 20 mm. All these considerations along with the desire for simplicity of the design led to the optical setup that is schematically shown in Figure 1. We will use Proscilica GC1290 camera (pixel size is 3.5 um x 3.5 um) with the motorized Computar H10Z1218 lens. The effective distance from the flag to the lens will be L = 1.5 m.

Figure 6: Flag optical transport showing Prosilica GC 1290 CCD coupled to Computar motorized zoom lense.

Computar Motorized Zoom Lenses provide remote control of focal length, iris and focus through the use a lens controller. It can be used where variable focal length and remote control are required as in this application.

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